Investigation of Manila Clam *(Tapes philippinarum)* Mortalities during the Spring of 1985 in the Strait of Georgia, with a Detailed Study of the Problem on Savary Island, British Columbia

S. M. Bower, R. Harbo, B. Adkins, and N. Bourne

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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INVESTIGATION OF MANILA CLAM (Tapes philippinarum) MORTALITIES DURING THE SPRING OF 1985 IN THE STRAIT OF GEORGIA, WITH A DETAILED STUDY OF THE PROBLEM ON SAVARY ISLAND, BRITISH COLUMBIA

by

S. M. Bower, R. Harbol[1], B. Adkins[1], and N. Bourne

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, British Columbia, Canada V9R 5K6

[1]Field Services Branch
South Coast Division
3225 Stephenson Point Road
Nanaimo, British Columbia V9T 1K3

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ABSTRACT

Bower, S. M., R. Harbo, B. Adkins, and N. Bourne. 1986. Investigation of manila clam (Tapes philippinarum) mortalities during the spring of 1985 in the Strait of Georgia, with a detailed study of the problem on Savary Island, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1444: 25 p.

High mortalities of manila clams (Tapes philippinarum) on six beaches; Hyacinthe Bay, Whaletown Bay, West Gorge Harbour, Squirrel Cove, Mink Island, and Savary Island, all in the northern end of the Strait of Georgia, as well as poor shelf life of clams harvested from these beaches, were reported and investigated during the spring of 1985. Other bivalve species on the same beaches as the dying manila clams and some manila clams below the moribund and dead ones were apparently not affected. Histological examination of moribund and "healthy" manila clams from affected beaches, and maintenance of manila clams from affected and unaffected beaches in the laboratory, did not reveal the presence of an infectious agent. The close proximity of affected and unaffected beaches, and the scattered distributon of affected beaches, suggest that if environmental factors were responsible for the mortalities, then adverse conditions were localized. Information from clam population surveys conducted on Savary Island since 1978 to estimate recruitment and the harvestable crop was used to estimate the impact of the mortalities on the population of manila clams from this island. Surveys conducted in April 1984 and July 1985, before and after the clam mortalities of 1985, showed that only manila clam populations from East Savary but not West Savary were significantly reduced in density with an estimated loss of about 416 t of harvestable stocks. Part of this reduction in harvestable stocks was attributable to a reduction between 1984 and 1985 in the estimated size of clam beds as well as to commercial harvesting and to the mortalities that occurred on this beach. However, the decline in manila clam stocks is within the natural fluctuations of manila clam populations on Savary Island and sufficient quantities of clams were still available for commercial harvest after the clam mortalities had ceased.

RESUME

Bower, S. M., R. Harbo, B. Adkins, and N. Bourne. 1986. Investigation of manila clam (Tapes philippinarum) mortalities during the spring of 1985 in the Strait of Georgia, with a detailed study of the problem on Savary Island, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1444: 25 p.

De fortes mortalités de palourdes des Philippines (Tapes philippinarum) sur six plages: baie Hyacinthe, baie Whaletown, havre West Gorge, anse Squirrel, île Mink et île Savary, toutes situées à l'extrémité septentrionale du détroit de Géorgie, ont été signalées et étudiées au printemps 1985. It en a été de même de la courte durée de conservation des palourdes récoltées sur ces plages. D'autres espèces de bivalves habitant ces même plages et des palourdes se trouvant en de ça des palourdes moribondes et mortes n'étaient apparemment pas touchées. Un examen histologique de palourdes moribondes et « en bonne santé » prélevées sur les plages affectées ainsi que le maintien en laboratoire de palourdes provenant de plages affectées et non affectées n'ont révélé la présence d'aucun agent infectieux. La proximité des plages affectées et non affectées, de même que l'éparpillement des plages affectées nous portent à croire que, si des facteurs environnementaux ont été responsables des mortalités, les conditions adverses étaient localisées. Les données recueillies au cours des relevés de populations de palourdes effectués dans l'île Savary depuis 1978 en vue d'estimer le recrutement et la masse récoltable ont été utilisées pour estimer la répercussion des mortalités sur la population de palourdes des Philippines sur cette île. Les relevés menés en avril 1984 et juillet 1985, avant et après les mortalités de 1985, indiquent que seule la population de palourdes de l'est, non celle de l'ouest, de l'île Savary a diminué de densité de façon significative, avec perte de stock récoltable estimée à environ 416 t. On a attribué une partie de cette diminution des stocks récoltables à une réduction entre 1984 et 1985 de la taille estimée des gisements de palourdes ainsi qu'à la récolte commerciale et aux mortalités qui se sont produites sur cette plage. Cependant, le déclin des stocks de palourdes des Philippines se situe dans les limites des fluctuations naturelles dans l'île Savary, et il est resté des quantités suffisantes pour la récolte commerciale après la cessation des mortalités.

INTRODUCTION

From mid-February through April of 1985, clam buyers who purchased clams from diggers at the north end of the Strait of Georgia found that manila clams (Tapes philippinarum) from some beaches had high mortalities and a poor shelf life. Native littleneck clams (Protothaca staminea) that were harvested from the same areas did not appear to be affected. At the same time, commercial clam diggers from these areas reported unusually large numbers of empty clam shells and dead clams on the surface of some beaches. Savary Island, located within the affected area, was one of the islands that had heavy mortalities among manila clams.

Savary Island has extensive populations of manila and littleneck clams on intertidal beaches along its north shore and they account for most of the clam landings from Fisheries Management Area 15 (Fig. 1). In recent years, annual reported landings ranged from 56 to 480 t of manila clams (20% to 30% of the B.C. total manila clam landings), from 6 to 47 t littleneck clams (5% to 10% of the B.C. total landings), and from 5 to 142 t of mixed manila and littleneck clams (Fisheries and Oceans Canada, Fisheries Management Pacific Region. Annual B.C. Catch Statistics, as reported on sales slips received by the Department of Fisheries and Oceans.) There is also an active recreational clam fishery on this island.

Clam population surveys on an annual or semiannual basis have been carried out on Savary Island since 1978 to estimate recruitment and the harvestable crop. Details of this program are described by Bourne and Adkins (1985). Since heavy mortalities of manila clams were reported from Savary Island, a comparison of results from population surveys of both manila and littleneck clams conducted in May 1984 and July 1985, before and after the reported clam mortalities of 1985 was used to estimate the extent of the mortalities. In an attempt to identify the causative agent, clams from Savary Island as well as other affected and unaffected beaches were examined histologically for a disease agent. Other clams from these locations were held in the laboratory to monitor mortality rate and to investigate, if a disease was present, whether or not it was infectious under laboratory conditions.

MATERIALS AND METHODS

COLLECTION OF CLAMS FOR DISEASE ANALYSIS

Manila clams were obtained and examined for the presence of a disease agent on three separate occasions; April 9, April 18, and May 22, 1985.

On April 9, 1985, manila clams were collected on the beach between the First and Second points on the north side of Savary Island (Fig. 2 and 3). Some weak clams lying on the surface of the beach and apparently healthy clams dug from the sand were preserved for histological examination (for details see below). Additional manila clams from the beach surface and some dug from the sand were kept cool and transported live to the Pacific Biological Station (PBS, Department of Fisheries and Oceans, Nanaimo, B.C.) to observe survival under laboratory conditions (see below). At this time, apparently healthy manila clams from Hernando Island and Theodosia Inlet, harvested by commercial diggers, were obtained from a clam buyer at Okeover Inlet (Fig. 4) and were preserved for histological examination.

On April 18, 1985, manila clams harvested by commercial diggers from several areas were obtained from a clam buyer at Fanny Bay on Vancouver Island. This buyer had stored the clams in onion sacks on a nearby beach for up to two weeks. Some of these clams were preserved for histological examination and others were kept cool and transported live to PBS for continued observation of survival in the laboratory. These clams originated from Fanny Bay; Whaletown Bay on Cortez Island; two sites from Area 27 (Fig. 1), Klaskino Inlet and an unknown site, on the west coast of Vancouver Island; and two sites from Area 25 (Fig. 1), Mary Basin and Zeballos, also on the west coast of Vancouver Island.

On May 22, 1985, manila clams were again collected on the beach between First and Second points on the north side of Savary Island. Three different groups of clams were harvested separately. One group consisted of "healthy" clams dug from the sand. A second group consisted of clams exposed on the beach surface by recent activity of the commercial clam diggers. The third group consisted of living clams found lying on the beach surface but not recently exposed by commercial digging activities. All clams were kept cool and within 19 hr after collection transported live to the Battelle-Northwest Marine Research Laboratory in Sequim, Washington. Some clams were examined alive microscopically and then fixed for histological examination. The remaining clams were held in tanks of flowing sea water and observed for subsequent mortalities.

HISTOLOGICAL EXAMINATION OF CLAMS

Living clams were shucked and overall condition of tissues examined superficially. Pieces of ctenidia (gills) of some clams were removed and placed in a drop of sea water between a glass slide and coverslip and these wet mount preparations were examined under a compound microscope (100 to 400x magnification).

Shucked clams were also preserved in either Bouin's fixative or Davidson's fixative with acetic acid and fixed for at least 48 hr. Three or four cross sections of each intact clam or just the ctenidia were embedded in wax and sections were cut at 7 µm. These tissue sections were stained with Harris modified haematoxylin and 0.5% alcoholic eosin. Stained sections were mounted in permount and examined under a compound microscope (100 to 1000x magnification).

STUDIES ON CLAM SURVIVAL IN THE LABORATORY

At PBS, all clams from each collection site were placed in separate nylon mesh sacks, with one sack per collection site, and all sacks were submerged in a large tank supplied with flow-through ambient sea water at about 10° C. At the Battelle Laboratory, Savary Island clams from the three different groups were each held in separate tanks supplied with sea water at about 12° C. Each day the clams were examined and dead or moribund gaping clams were counted and removed. Some of the moribund clams were preserved in Davidson's fixative with acetic acid for histological examination as described above.

SURVEY OF CLAM POPULATIONS ON SAVARY ISLAND

Sampling methods on Savary Island beaches were the same in both May 1984 and July 1985. Three distinct beach areas were identified and sampled; one east of First Point, one between First and Second points, and one on the west end of the island near Indian Point (Fig. 2 and 3). In the results, the data from the plots on the two beaches east of Second Point are grouped and designated as East Savary, and the data from the plots near Indian Point are designated as West Savary.

Sample plots were either 0.5 or 0.25 m^2 in area and all were dug to a depth of 20 cm with a short handled rake. At each plot the substrate was carefully sifted through the fingers as it was removed and all clams put into labelled bags. The soil was again sifted through the fingers as it was reworked back into the plot and any remaining clams collected. This method is effective in sampling 95% of the clams 20 mm in shell length and larger (Bourne and Adkins 1985). In 1984 sample plots were set out 100 m apart along a transect 150 to 200 m seaward and parallel to the break at the top of the intertidal beach. On the beach between First and Second points an additional three plots were sampled along a transect 300 to 400 m seaward of the break and on the beach near Indian Point three plots were sampled along a transect 100 m seaward of the break (Fig. 2). In 1985 sample plots were again set out 100 m apart along a transect 100 to 200 m parallel to and seaward of the break in all three areas. A second parallel transect was set out 100 m seaward of this in the area between First and Second points. On the beach near Indian Point an additional four plots were sampled 100 m seaward and two plots were sampled 50 m shoreward of this transect (Fig. 3).

Clams from each sample plot were frozen and returned to the laboratory. Subsequently, shell lengths to the nearest mm and whole weights to the nearest g were recorded in legal and sublegal categories for each species. The commercial clam fishery is regulated by a legal size limit of 38 mm shell length for both manila and littleneck clams. The sport fishery on the other hand has no size restriction but is limited by a daily bag limit of 75 clams per person. In 1984 shell lengths of clams from only five plots were measured but in 1985 clams from all sample plots were measured.

Harvestable beach areas (beds) were estimated by digging a series of 0.25 m^2 test plots while pacing off the seaward and lateral distribution of clams for each bed. The limits of distribution were identified when there were less than 3 clams in more than 2 of the test plots. These data, together with estimates of densities from all plots, were used to determine the total harvestable stock for the clam beds.

Student's t-test was used to test the significance of changes in stock densities from 1984 to 1985.

RESULTS

CONDITION OF MANILA CLAMS AT TIME OF COLLECTION FOR DISEASE ANALYSIS

During the visit to Savary Island on April 9, a large patch of beach between First and Second points was found strewn with many empty shells, the majority of which were manila clams, although the shells of a few littleneck clams were also observed. In addition, there were many living manila clams either lying on the beach surface or partially protruding from the sand. The majority of the living clams exposed on the beach surface were weak and could be opened by prying them apart using finger pressure alone. Superficially, the tissues looked emaciated and there was no evidence of gonadal development. At least 3 cross sections through each of 8 of these living but weak clams were examined histologically. All 8 clams showed varying degrees of damage to the ctenidial epithelium from an extreme of virtually no epithelium left on the ctenidia of 2 clams to only a few patches of sloughing epithelium on the proximal regions of the ctenidial arches of 2 others. No pathogen was identified in any of the tissues of the 8 clams.

The sand below the weak clams contained apparently healthy manila clams that were difficult to open even with a shucking knife. Histologically, the tissues of 3 of 4 of these clams appeared normal while one clam had a few small patches of sloughing epithelial cells on the proximal region of the ctenidial arches. Again, no pathogen was seen in any of the tissues of these 4 clams. Apart from a few littleneck clam shells that were also observed on top of the beach with the manila clams, none of the other shellfish species on the beach (butter clams Saxidomus giganteus, cockles Clinocardium nuttallii, oysters Crassostrea gigas, and blue mussels Mytilus edulis) seemed to be affected.

On April 9, a clam buyer at Okeover Inlet had no reports of unusually high clam mortalities from commercial clam diggers on Hernando Island, Theodosia Inlet, and Okeover Inlet, and there were no problems with the shelf life of manila clams from these areas. Histological samples of 2 of 4 manila clams from Hernando Island, and the only clam examined from a beach

at Theodosia Inlet revealed only a few small patches of ctenidial epithelium that appeared to be sloughing. The remaining tissues of these clams and all tissues from the other two clams from Hernando Island appeared normal and no pathogens were observed in any of the clam tissues.

Manila clams obtained from a clam buyer at Fanny Bay on April 18, varied in condition depending on the source of the clams. Approximately 10% of the clams dug from the Fanny Bay area were dead in the sacks. Four living clams were examined fresh. These clams did not appear emaciated as did clams from Savary Island and all tissues appeared normal by wet mount microscopic examination. Six additional clams were examined histologically but no evidence of pathology was observed. Clams from Whaletown Bay on Cortez Island were suffering less then 10% mortalities during storage and shucked living individuals from there did not look as emaciated as clams observed on the beach surface of Savary Island. However, of 5 clams examined histologically, all had epithelium sloughing from the ctenidia in patches which varied in extent between individuals. Tissues of these clams appeared edematous and the intestinal tracts of two other clams were greatly distended but apparently empty. Again, no disease producing organisms were observed. The majority of the clams in sacks from Klaskino Inlet were dead or dying. Of the 3 clams examined histologically, 2 were normal and the third had a large patch on one ctenidia that appeared badly damaged with the epithelium sloughing but all other areas of the ctenidia examined appeared normal. Clams harvested from Area 27 (exact location not known) appeared healthy and 2 clams examined histologically both appeared normal. Clams in sacks from Zeballos and Mary Basin both appeared healthy and the one clam from Zeballos examined histologically appeared normal. However, the one clam from Mary Basin examined histologically had almost no epithelium remaining on most of the ctenidia.

On the second visit to Savary Island on May 22, 1985, numerous empty shells were still evident on the beach but the number of moribund clams lying on the beach surface was greatly reduced. It took about 2 1/2 hr for 2 people to collect 32 moribund specimens, all of which were manila clams, whereas these clams were readily obtained during the visit on April 9. Many apparently healthy clams, including manila clams, were present in the sand below the empty shells and 9 commercial clam diggers harvesting clams from the beach on May 22 did not report a problem with shelf life of harvested clams. Only manila clams were collected, and all clams transported to the Battelle Laboratory in Sequim, Washington survived. Within 24 hr, 10 of the 32 clams collected from the surface of the beach and 10 of the 50 clams dug from the sand were shucked and examined superficially. All clams appeared somewhat emaciated and some of the clams from both groups showed varying degrees of bright yellow pigmentation on the inside of the siphon. However, the edge of the mantle of some of the clams collected from the beach surface appeared to be damaged and the ctenidia seemed slightly darker than those of clams dug from the sand. Wet mount preparations of ctenidia of two of the clams with darker gills appeared to show some sloughing and disintegration of epithelial cells but did not reveal an infectious agent. Histological preparations of these 10 clams collected from the surface of the beach did not reveal any infectious agents and the ctenidial epithelium of all 10 clams appeared normal.

SURVIVAL OF CLAMS IN THE LABORATORY

The majority of the clams that died in the laboratory died within the first 10 days (Table 1). Even though clams collected on April 9 and 18 were kept together in one tank (but in separate mesh bags for each location) at PBS, mortalities were not found to increase with time and clams from some locations (Zeballos, and the unknown location in Area 27) either had no or very few mortalities. At the Battelle laboratory, only clams collected from the surface of the beach suffered mortalities (40%) in captivity.

REPORTED LOCATIONS OF MANILA CLAM MORTALITIES

In March, April, and early May 1985, reports of manila clam mortalities in the Strait of Georgia were submitted to the Department of Fisheries and Oceans. Six localities that were reported as having unusually high clam mortalities were: Savary Island, Mink Island, Hyacinth Bay, Whaletown Bay, West Gorge Harbour, and Squirrel Cove (Fig. 4). Even in these locations, apparently only some patches of the beach seemed to be affected. Other beaches in the same area, such as on Hernando Island, in Okeover Inlet and in Theodosia Inlet, apparently had no unusually high manila clam mortalities. Manila clam mortalities were not reported on any beaches south of Savary Island.

SURVEY OF CLAM POPULATIONS ON SAVARY ISLAND

When the survey of the Savary Island clam population was conducted in July 1985, there were unusually high numbers of recently exposed shells (Fig. 5 and 6), but no dead or decomposing clams were found on the surface or buried in the substrate. None of the clams observed appeared to be gaping, weakened, or distressed.

Density of manila clams in the two beds on the north end of Savary Island (East Savary) were significantly reduced between 1984 and 1985 (Table 2). Although the densities of littleneck clams on East Savary and the densities of both manila and littleneck clams on West Savary seemed to be slightly reduced in the same period, the differences between the mean densities of the two years were not significant (Student's t-test, $P > 0.05$). On East Savary, 83.5% of the losses in density of manila clams occurred amongst sublegal sized clams (length $\geq 20 < 38$ mm). In May 1984, about 7.4% of the combined manila and littleneck clams from plots on East Savary were littleneck clams. However, by July 1985, because of differences in percentage of mortalities between the two species, about 23.4% were littleneck clams.

The mean estimated standing stock of legal sized clams (length ≥ 38 mm) on Savary Island beaches declined significantly (Student's t-test, $P > 0.05$) from 716 t of manila clams and 118 t of littleneck clams in 1984 to 334 t of manila clams (a decline of 382 t) and 46 t of littleneck clams (a decline of 72 t) in 1985 (Table 3). This decline seemed to occur in the beds of East Savary where there was a significant (Student's t test, $P > 0.05$) decline in the estimated harvestable stocks (legal sized clams) from 1984 to 1985 of 416 t for manila clams and 86 t for littleneck clams. There was no significant difference in the estimated legal harvestable stocks in the West Savary bed. In fact, there was a slight increase in mean estimates of 17 t for manila clams and 3 t for littleneck clams.

Overall total decline in estimated standing stocks between May 1984 and July 1985 was 72.5% for manila clams and 48.3% for littlenecks clams (Table 3). Again, almost all losses in stocks occurred in the two beds of East Savary. However, during this period, the estimated harvestable area on Savary Island decreased by 21.3% (from 69.9 ha in 1984 to 55.0 ha in 1985, Table 3). This decrease in clam bed size occurred only in the area between First and Second points (East Savary) where harvestable quantities of clams extended more than 400 m seaward of the break in 1984, but less than 300 m seaward of the break in 1985. Thus, the estimated harvestable beach area east of Second Point was 44.9 ha in 1984 and only 30.0 ha in 1985.

DISCUSSION

Mass mortalities of bivalves in British Columbia have not been common and no diseases have been reported from clams in this Province. However, there are three instances of parasites being associated with abnormal exposure of littleneck clams (P. staminea) on the beach surface of beds in Humboldt Bay, California (Sparks and Chew 1966); in Morro Bay, California (rough-sided littleneck clams, Protothaca laciniata, Katkansky and Warner 1969); and in Sequim Bay, Washington (Morado et al. 1984). In Humboldt Bay and Morro Bay, all tissues of exposed littleneck clams were found heavily infected with plerocercoids of a tetraphyllidean cestode (Echeneibothrium sp.) (Sparks and Chew 1966; Katkansky and Warner 1969). During a later study of the same clam population in Humboldt Bay, similar plerocercoids were again observed in littleneck clams but the intensity of infection was less (a maximum of 8 cysts per clam in contrast to more than 35 cysts present in a cross section of a clam as observed in the 1966 study) and no clams were observed on the surface of the beds (Warner and Katkansky 1969). In Sequim Bay, during the summer of 1980, the kidneys of numerous exposed littleneck clams were found heavily parasitized by a coccidian protozoa thought to be of an undescribed genus and species (Morado et al.1984). Only two other reports of abnormal conditions in bivalve molluscs of the Family Veneridae are known from the Pacific Coast of North America. One is of a benign polypoid tumor on the foot of 1 of 183 Saxidomus giganteus from Sequim Bay, Washington (Pauley 1967) and the other is of rare occurrences of the nonpathogenic

parasitic copepod Mytilicola orientalis in the intestinal lumen of the same species of clam in British Columbia (Bernard 1969). None of these parasites and conditions were observed in any of the 45 manila clams from 9 locations that were examined histologically. Also, no other recognizable disease agents were observed. In an attempt to determine whether or not a virus was present, the ultrastructure of epithelial cells sloughing from the ctenidia of a manila clam from Savary Island was examined. These sloughing cells were removed from a wax block, where they were embedded for the purpose of histological examination under the light microscope, and were processed for electron microscopy. No viruses were observed (pers. comm., Ralph Elston).

In general, clams from populations that had a high prevalence of ctenidia damage (clams from Whaletown Bay and from the surface of the beach on East Savary Island) also had poor survival in the laboratory (Table 1). However, clams obtained from clam buyers may not constitute a reliable sample. It is possible that such clams may have been mishandled by exposing them to inclement conditions, such as freezing or excessive drying, during transit or by leaving sacks of clams on the beach for prolonged periods. This may result in reduced "shelf life" or cause direct clam mortalities, thus making it difficult to identify the cause of mortality at this stage in the marketing process.

It has also been noted in the past, that on occasion buyers may refuse to purchase all the harvested clams because of poor prices or limited markets. On Savary Island this has resulted in sacks of clams being deserted on the beach by inexperienced or transient diggers. These clams may eventually be spread on the beach making it appear as though clams were dying for "unexplained" reasons. The clam mortalities on Savary Island in the late winter of 1985 seemed to be too extensive to be attributable to such a human-induced cause.

Beaches that were reported as being affected were interspersed amongst beaches with no apparent problem (Fig. 4), and some areas of affected beaches seemed not to show abnormally high mortalities of clams. Therefore, it is difficult to attribute the mortalities of the manila clams to climatic conditions. However, a combination of marginally bad climatic conditions, angle of exposure of some beach sections to these inclement conditions, and beach gravel conditions may have resulted in some mortalities in some areas. The temporal pattern of mortalities on affected beaches may also support this hypothesis. On East Savary Island on April 9, 1985, many empty shells of recently dead clams as well as some emaciated moribund specimens with damaged ctenidia epithelium were observed on the beach surface. By May 22, moribund clams were difficult to find and none were observed by July. If the original damage inflicted on the clams was marginal, it would likely take a longer period of time for the less severely affected clams to succumb while others of this group would survive. Thus, cold temperatures and possible partial freezing of clams cannot be ruled out as a cause or contributing factor to the mortalities.

In the present study, manila clams on Savary Island located higher on the beach suffered much higher mortalities than littleneck clams which mainly occur lower down in the intertidal zone. Although a few shells of littleneck clams were observed on the beach in April 1985, the density of

living clams of this species was not significantly different between the surveys conducted before and after the high mortalities that occurred amongst the manila clams (Table 2). Heavy mortalities of manila clams have been previously reported in abnormally cold winters because these clams occupy upper beach levels and burrow only to shallow depths (10 cm maximum) in the sediments (Bourne 1982). Manila clams must be able to tolerate occasional freezing conditions considering their distribution high on the beach. Kanwisher (1955) suggested that the ability to prevent internal ice formation may be a principal reason, along with the ability to withstand dehydration, that allows intertidal species to survive low tides during the winter. Nevertheless, some clam species, such as horse clams (Tresus nuttallii), are subject to mortalities during periods of freezing temperatures, which limits their distribution to the lower intertidal zone in many areas (Swan and Finucane 1952).

Both manila and littleneck clam stocks on Savary Island in July 1985 (after the high mortalities that occurred earlier that year) appeared to be within the natural population fluctuations of clams on this beach over the past seven years (Bourne and Adkins 1985). However, since 1978, there has not been reports of obvious mortalities nor large numbers of exposed shell on this beach. If the decline in clam stocks is actually within the natural fluctuations of clam populations on Savary Island, then the mortalities may be due to density dependent or cyclic phenomena. Unfortunately, population data on clam stocks of the other affected and unaffected beaches are not available, making it impossible to generalize this explanation to the mortalities that occurred on the other beaches.

The decline in estimated clam bearing area on East Savary beaches from 69.9 ha in May 1984 to 55.0 ha in July 1985 may be from a variety of causes. Although lateral distribution remained relatively unchanged, the seaward distribution changed from more than 400 m in 1984 to less than 300 m in 1985. Bourne and Adkins (1985) observed shifting of sand and gravel bars over the period of their surveys from 1978 to 1983. It is also likely that sand bars shifted because of storms in the winter of 1984-1985, thereby affecting clam distribution. Thus, some of the die-off of clams, at least on Savary Island, may be attributed to changes in habitat conditions.

Although there was a significant decline in total estimated harvestable stocks of clams on Savary Island between 1984 and 1985, there were sufficient quantities of clams available for commercial harvest. The estimated legal sized harvestable stocks were between 206 and 463 t for manila clams and between 15 and 76 t for littleneck clams for all areas combined (Table 3). Based on these stock estimates, an opening for commercial clam harvest was recommended for Savary Island in November, 1985 with monitoring and enforcement of the minimum size limit.

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Table 1. Survival in the laboratory of Manila clams (Tapes philippinarum) from different sources.

Source of clams	Date clams obtained[a] 1985	Number of clams held	Number of clams dead within first 10 days (%)	Total clams dead by day 55 (%)
Savary Island, from surface and dug from beach	April 9	128	24 (18.8)	35 (27.3)
Whaletown Bay, Cortez Island	April 18	24	18 (75.0)	19 (79.2)
Klaskino Inlet	April 18	33	13 (39.3)	18 (54.6)
Area 27, location unknown	April 18	34	2 (5.9)	2 (5.9)
Mary Basin	April 18	31	23 (74.2)	24 (77.4)
Zeballos	April 18	59	0	0
Savary Island from surface of beach	May 22	20	8 (40.0)	8 (40.0)
Savary Island exposed by commercial diggers	May 22	20	0	0
Savary Island - dug from sand	May 22	40	0	0

[a]Clams obtained on April 9 and May 22, 1985, were collected from the beach on that day, but clams obtained on April 18 were from a clam buyer at Fanny Bay and may have already been stored for up to two weeks prior to April 18.

Table 2. Estimates[a] of manila clam (Tapes philippinarum) and littleneck clam (Protothaca staminea) densities (kg/m^2) on Savary Island in May 1984 and July 1985.

Locality:	East Savary			West Savary		
Survey date:	May/84	July/85	Significance[c]	May/84	July/85	Significance[c]
Number of plots[b]	18	20	between means	13	15	between means
Manila clams:						
Total	5.63±3.47(3.84-7.41)	0.85±0.52(0.61-1.09)	S	3.12±1.82(2.03-4.22)	2.57±2.18(1.36-3.77)	NS
Legal size	1.22±0.87(0.77-1.66)	0.43±0.41(0.24-0.63)	S	0.77±0.54(0.45-1.10)	0.84±0.91(0.34-1.34)	NS
Sublegal size	4.41±3.24(2.74-6.08)	0.42±0.37(0.25-0.59)	S	2.35±1.61(1.38-3.32)	1.73±1.77(0.75-2.70)	NS
Littleneck clams:						
Total	0.45±0.50(0.19-0.71)	0.26±0.26(0.13-0.38)	NS	0.19±0.21(0.07-0.32)	0.18±0.19(0.08-0.28)	NS
Legal size	0.25±0.34(0.08-0.43)	0.09±0.19(0.00-0.18)	NS	0.07±0.09(0.01-0.12)	0.08±0.13(0.01-0.14)	NS
Sublegal size	0.20±0.27(0.06-0.34)	0.17±0.13(0.10-0.23)	NS	0.13±0.19(0.01-0.24)	0.10±0.12(0.04-0.17)	NS

[a]Estimates are recorded as mean ± standard deviation (lower and upper 95% confidence limits) in kg/m^2 for the plots surveyed. Total includes a combined estimate of all legal sized clams (length $\geq$ 38 mm) and sublegal sized clams (length $\geq$ 20 mm and < 38 mm)

[b]Each plot was either 0.5 or 0.25 m^2 in area and was dug to a depth of 20 cm

[c]Student's t-test: NS=not significant at $P>0.05$; S=significant at $P<0.05$.

Table 3. Estimates[a] of manila clam (Tapes philippinarum) and littleneck clam (Protothaca staminea) standing stock (in tonnes) on Savary Island in May 1984 and July 1985 and the percent decline[b] in these stocks between these dates.

Locality:	All Plots		East Savary		West Savary	
Survey date:	May/84	July/84	May/84	July/84	May/84	July/84
Estimated harvestable area (ha):	69.9	55.0	44.9	30.0	25.0	25.0
Manila clams:						
Total	3173(2356-3989)	872(563-1182)	2526(1725-3327)	255(182-328)	781(506-1055)	642(341-943)
Percent decline	72.5%		89.9%		17.8%	
Legal size	716(514-918)	334(206-463)	546(345-747)	130(72-188)	194(112-275)	211(85-336)
Percent decline	53.4%		76.2%		none	
Sublegal size	2458(1716-3200)	538(292-784)	1980(1231-2729)	125(74-177)	587(344-830)	431(187-676)
Percent decline	78.1%		93.7%		26.6%	
Littleneck clams:						
Total	236(126-346)	122(80-164)	202(86-318)	77(40-113)	48(16-80)	45(19-70)
Percent decline	48.3%		61.9%		6.3%	
Legal size	118(45-191)	46(15-76)	113(34-191)	27(0-54)	16(3-29)	19(1-36)
Percent decline	61.0%		76.1%		none	
Sublegal size	118(55-181)	76(53-100)	89(27-152)	50(69-31)	32(3-61)	26(9-42)
Percent decline	35.6%		43.8%		18.8%	

[a]Estimates are recorded as mean with lower and upper 95% confidence limits in parentheses, in tonnes calculated by multiplying the estimates of density (Table 2) from the sample plots with the harvestable beach area. Total, includes a combined estimate of all legal size clams (length $\geq$ 38 mm) and sublegal sized clams (length $\geq$ 20 mm and < 38 mm)

[b]Percent decline is the difference in the mean standing stock estimate between May 1984 and July 1985 as a percentage of the stock in May 1984

Fig. 1. Map showing the Fisheries Statistical Areas from the British Columbia south coast district. Savary Island in Area 15 is indicated by an arrow.

READ CAREFULLY

1. Reporting of all catches to the Dept of Fisheries and Oceans is the responsibility of the fisherman and a condition of licence renewal.
2. Accurate catch reports must include the map number or numbers showing the area in which your fish were caught.
3. The statistical areas shown on this map are to be used as a guide only. For more exact information refer to the Pacific Fishery Management Area Regulations.

● Dept of Fisheries and Oceans Office

Statistical areas are divided by red lines

Surfline

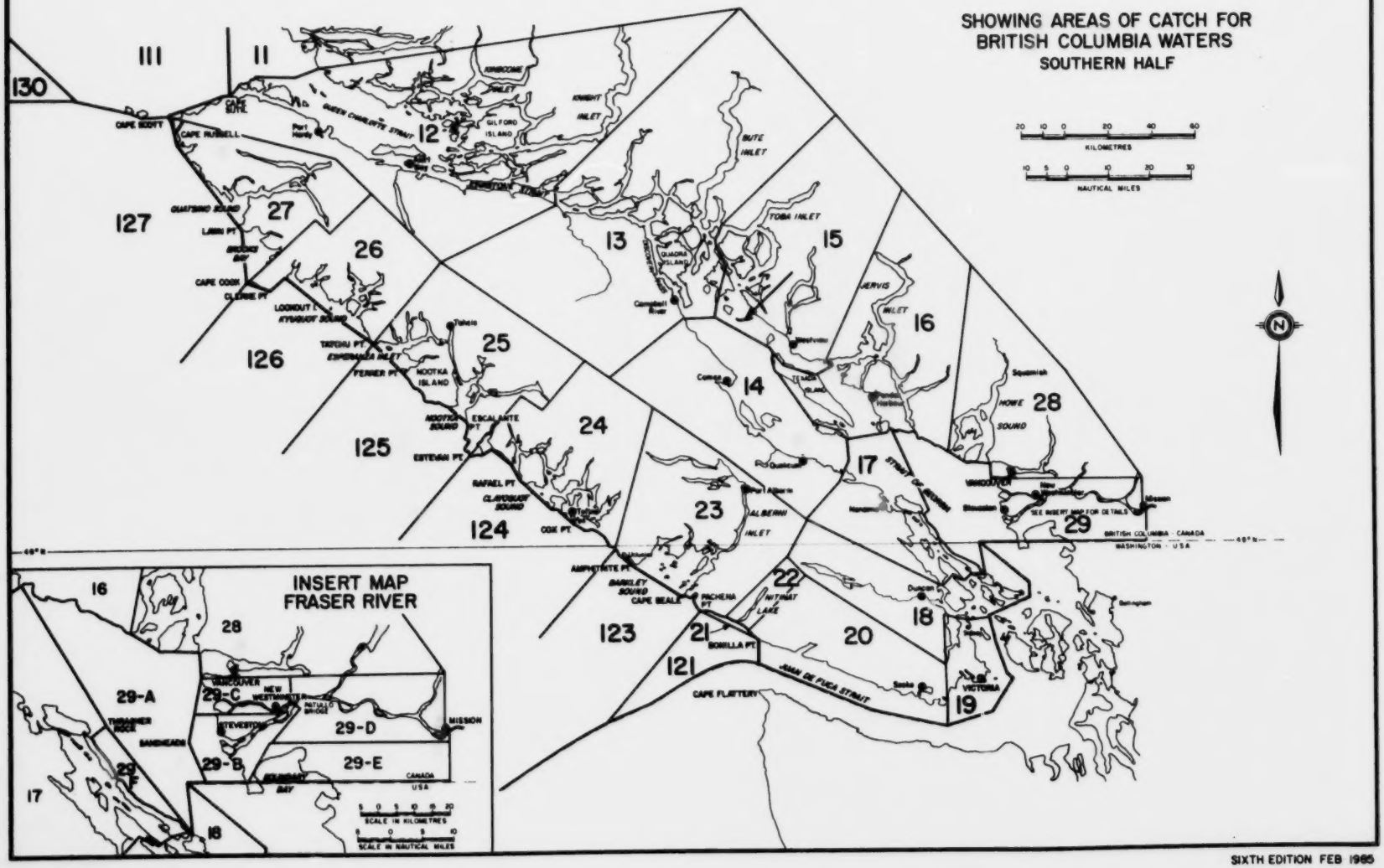
Note: All areas revised February 1985

Fisheries and Oceans / Pêches et Océans

Canada

STATISTICAL AREA MAP

SHOWING AREAS OF CATCH FOR BRITISH COLUMBIA WATERS SOUTHERN HALF



SIXTH EDITION FEB 1985

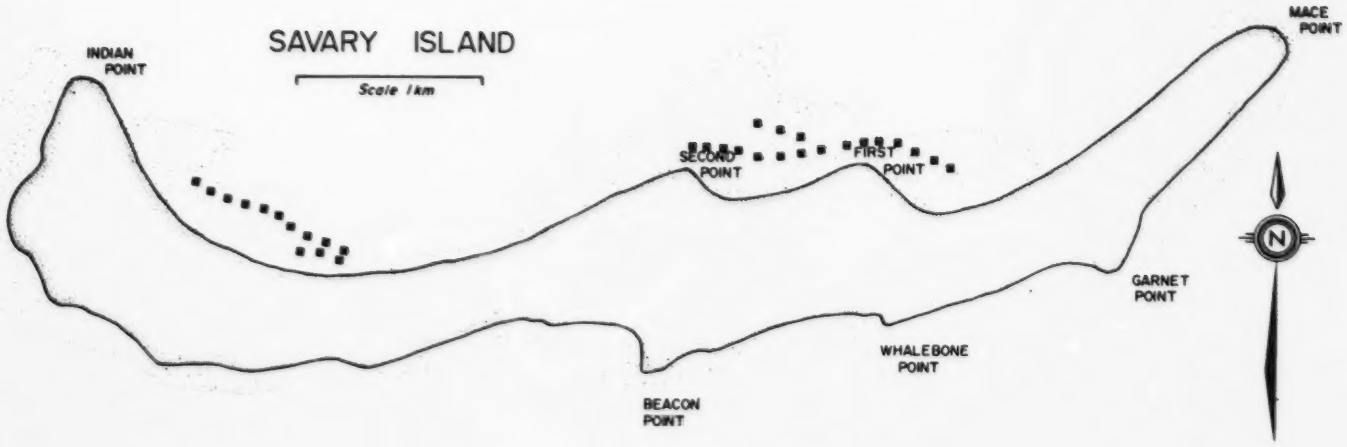


Fig. 2. Map of Savary Island showing location of sample plots (solid squares) of May 1984 survey.

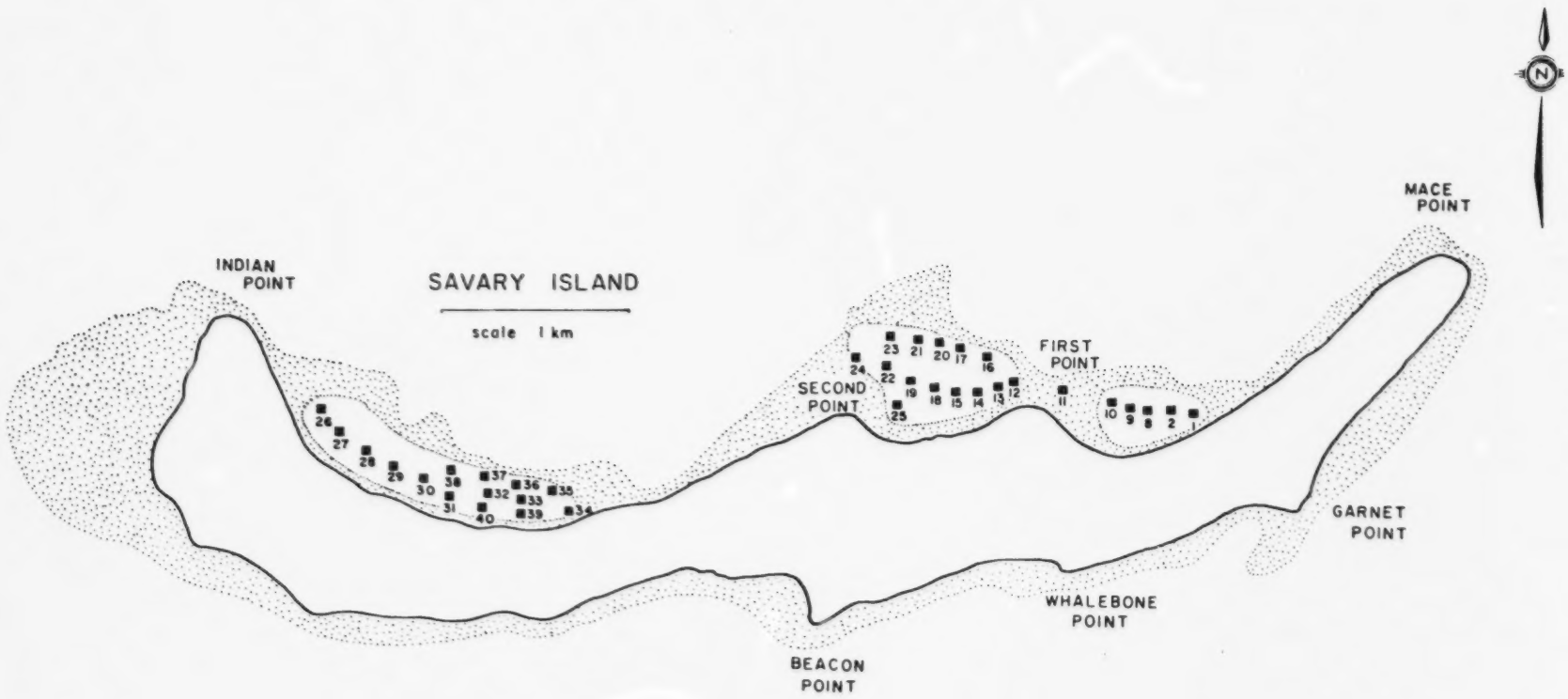
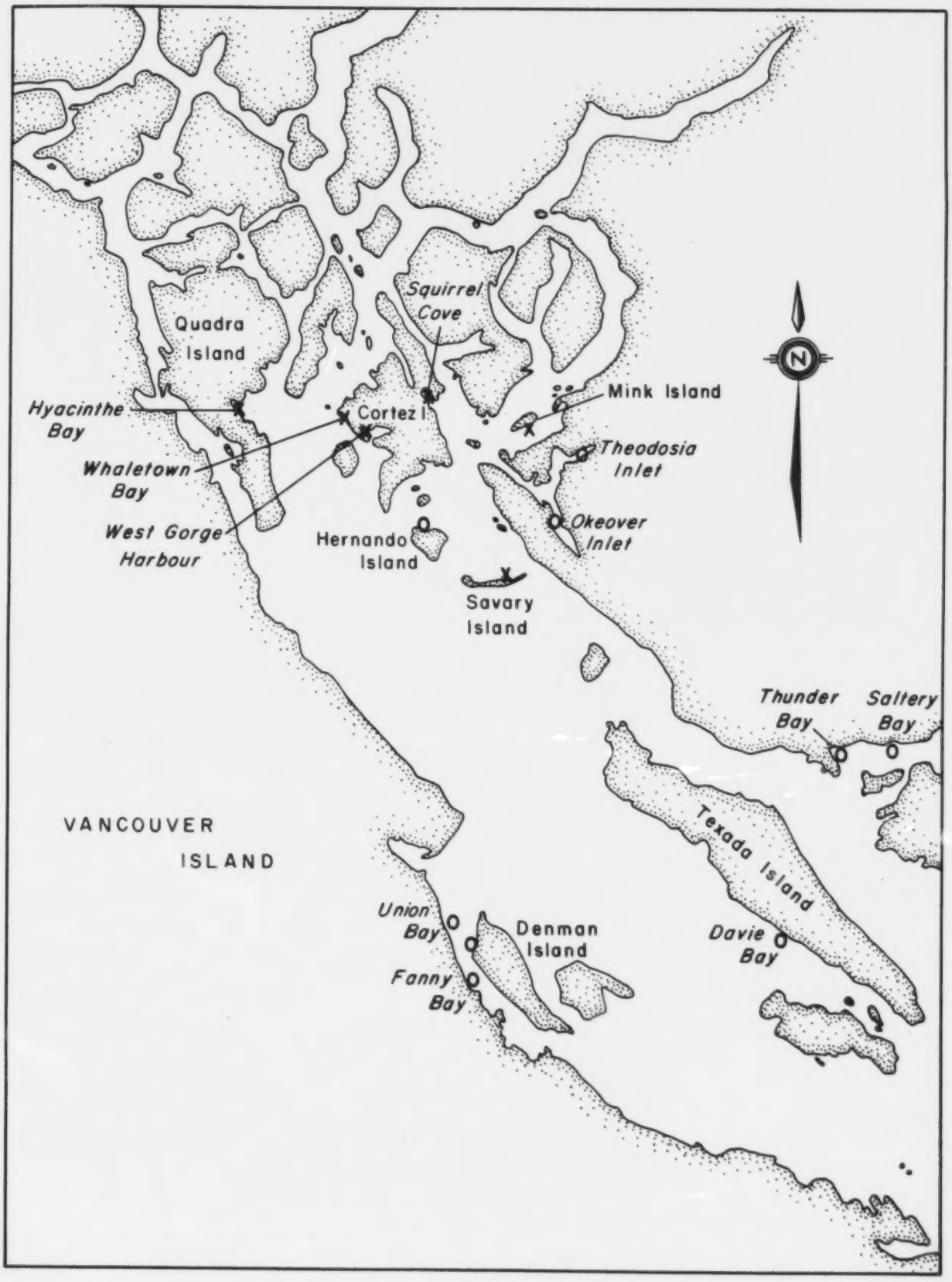


Fig. 3. Map of Savary Island with sample plots (solid squares) of July 1985 survey and areas of clam beds indicated.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Quadra Island
Hyacinthe Bay
Cortez I
Mink Island
Theodosia Inlet
Whaletown Bay
West Gorge Harbour
Hernando Island
Okeover Inlet
Savary Island
Thunder Bay
Saltery Bay
VANCOUVER ISLAND
Texada Island
Union Bay
Denman Island
Davie Bay
Fanny Bay
N

Fig. 5. Photograph off First Point on Savary Island in August 1985, illustrating the abundance of shells of recently dead manila clams (Tapes philippinarum) on the beach.

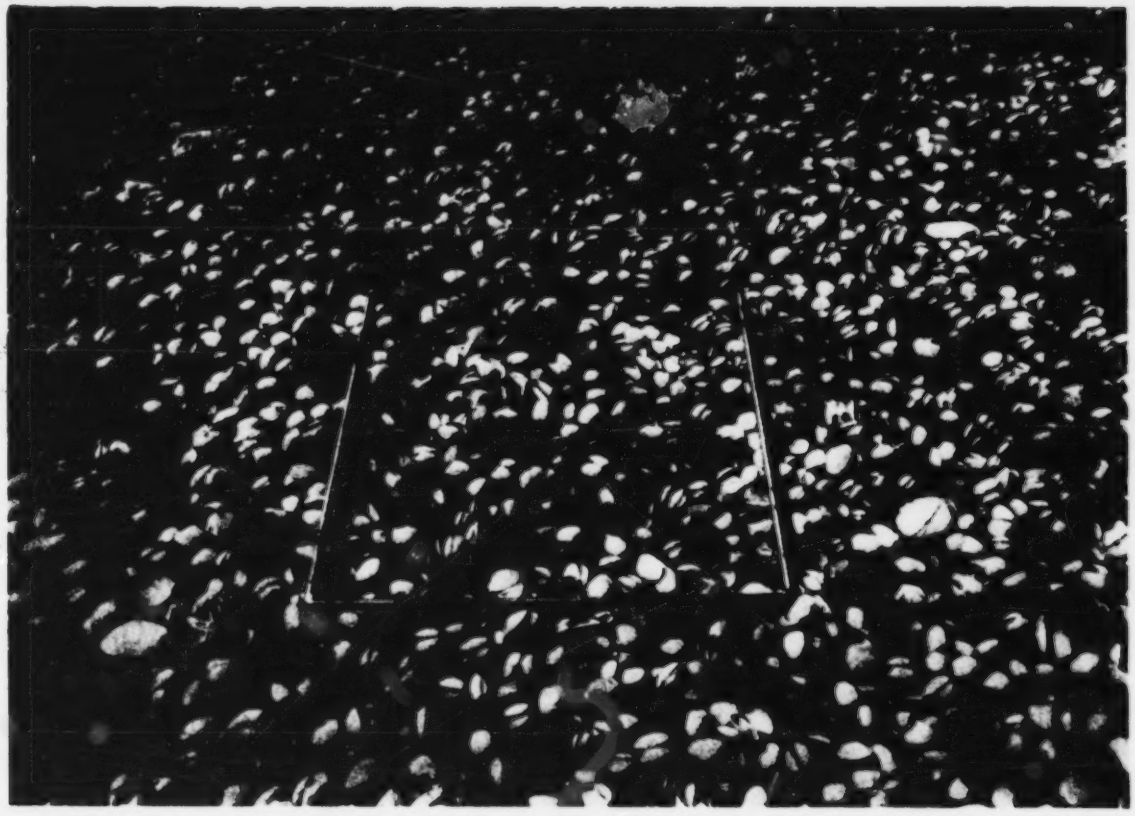

Fig. 6. Close up of Figure 5 with a 0.25 m^2 sample quadrat plot in place.